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28 JUNE 1963

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GEMINI LAUNCH VEHICLE MONITORING IN THE IMCC

CONTRACT NO NAS 9-366

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MANNED SPACECRAFT CENTER
HOUSTON TEXAS

PHILCO
A SUBSIDIARY OF
Ford Motor Company

WESTERN DEVELOPMENT LABORATORIES
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GEMINI LAUNCH VEHICLE MONITORING IN THE IMCC

Contract No NAS 9-366

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Submitted to the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
Houston, Texas

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ABSTRACT

PHILCO WDL-TR-E152 UNCLASSIFIED
GEMINI LAUNCH VEHICLE
MONITORING IN THE IMCC 38 pages
28 JUNE 1963 Contract NAS 9-366

This report, one of a series under Contract NAS 9-366, discusses operating concepts for the Launch Vehicle Systems Engineer (LVSE) and the Booster Telemetry Engineer (BTE) In addition, the report recommends display devices based on our understanding of LVSE and BTE functions and information requirements

Subjects covered by the report are a description of the responsibilities of the LVSE, BTE and AFDO, information requirements of the LVSE and the BTE, logic material illustrating LVSE functions (and the relation of these

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functions to the use of his displays), a discussion of the interactions between the LVSE and the BTE, and a discussion of display/control concepts for the LVSE and BTE

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This study report which has been prepared under Contract NAS 9-366 is distributed for your information The subject of this document should not be regarded as a firm Manned Spacecraft Center position nor should it commit the Manned Spacecraft Center This document reflects the recommendations of the Philco Corporation as a result of their study effort

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SECTION 1

INTRODUCTION

1 1 GENERAL

This report, one of a series under Contract NAS 9-366, discusses operating concepts for the Launch Vehicle Systems Engineer (LVSE) and the Booster Telemetry Engineer (BTE) In addition, the report recommends display devices based on our understanding of LVSE and BTE functions and information requirements

1 2 SCOPE

The following subparagraphs contain short descriptions of the various sections in this report

Section 2 This section briefly describes the responsibilities of the LVSE, the BTE and the Guidance Switchover monitor (AFDO)

Section 3 This section presents the information requirements of the LVSE and the BTE These information requirements are then related to specific display devices and formats for each engineer

Section 4 This section presents a logic diagram illustrating LVSE functions and relates these functions to the use of his displays

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Note Publication does not imply NASA approval of the information and operating concepts contained in this report, the document is published primarily to convey recommendations from the Philco Study Contract Group to the NASA Flight Operations Division

Section 5 This section presents a discussion of the interactions between the LVSE and the BTE

Section 6 This section presents a discussion of display/control concepts for the LVSE and BTE

SECTION 2

RESPONSIBILITIES OF THE LVSE, BTE AND AFDO

2 1 LAUNCH VEHICLE SYSTEMS ENGINEER

The Gemini Launch Vehicle (GLV) incorporates in its systems a Malfunction Detection System (MDS), the primary purpose of which is to ensure the safety of the flight crew The MDS senses and provides indications of potentially catastrophic failures in GLV performance In addition, the MDS provides a guidance switchover signal for certain failures Since the astronauts alone make the final decision to abort from the GLV, the MDS functions to increase the astronauts' time for reaction to a failure Should a malfunction occur in the early moments of flight, the flight crew would receive an indication of the failure (or impending failure) on the space craft display/control panel and would take the appropriate action The period in which the MDS operates, nowever, is also a period of high stress for the flight crew, therefore, a "backup" monitor for the MDS is deemed necessary This "backup" function will be the primary responsibility of the LVSE

The LVSE will monitor the MDS parameters received from the GLV and spacecraft in greater detail than will the flight crew, and in some cases he may be able to detect impending failures before the MDS reacts In this event, the LVSE will take his principal action, that of recommending an abort to the flight crew It is assumed that two primary methods of recommending aborts are available to the LVSE for simultaneous use (1) a console (push button) originated digital command which lights an abort

lamp on the flight crew panel, and (2) a voice override capability to cut in on spacecraft communication and cue an abort via direct voice contact

Thus, the LVSE's primary responsibility is to recommend an abort to the astronauts with sufficient time margin to allow them to initiate the abort safely

2 2 BOOSTER TELEMETRY ENGINEER

The BTE is an assistant to the LVSE and most probably will be a contractor-supplied engineer (the term BTE is used in WDL-TR-E143 and is synonymous with the term Assistant Launch Vehicle Engineer used in NASA documents) As an assistant, the BTE will be responsible for analysis of certain MDS telemetry parameters which, if degrading slowly, could indicate either a guidance switchover or a potentially catastrophic system failure It is clear that the BTE will advise the LVSE of any impending failure he detects It is recommended that the BTE also be responsible for advising the AFDO of any failure which could result in a guidance switchover This interface will be clarified in subsequent sections of this report

2 3 ASSISTANT FLIGHT DYNAMICS OFFICER (GUIDANCE SWITCHOVER MONITOR)

The AFDO is responsible during the launch phase for initiating (through the astronauts) a guidance switchover in the event that a "slow" failure* presents a choice of times to perform the switchover

* "Slow" failures are defined as hazardous situations which allow time for human reaction

The GLV incorporates an automatic guidance switchover capability which will react rapidly for any sudden failure in guidance Should a gradual rate, drift or loss of hydraulic pressure occur, some amount of time would probably be available to effect a switchover This latter case is the special concern of the AFDO, who would decide the proper moment to initiate a manual switchover

Since an in-flight guidance switchover will be more dangerous during some portions of the launch (due to possible vehicle structural failures) it is projected that the AFDO will require displays which graphically present guidance switchover exclusion periods He will, we feel, also be monitoring a number of displays of telemetered guidance equipment outputs such as roll, pitch and yaw rates, etc , from both guidance systems (RGS & IGS) It is also recommended that the AFDO have voice contact with the spacecraft for this launch period Although the failures on which he acts are termed "slow", some may be of only seconds duration, and the delay in reaching the astronauts via the Spacecraft Communicator could prove to be troublesome Our intent is not to analyze AFDO functions, but rather to point up what we feel are logical interactions between the LVSE and the AFDO and between the BTE and the AFDO (Further discussion is presented elsewhere in this report)

SECTION 3

INFORMATION REQUIREMENTS

3 1 LAUNCH VEHICLE SYSTEMS ENGINEER

The LVSE information requirements (consistent with the philosophy of operation developed in this report) are presented in Table 3-1 The left column lists the items of information that would be required at the LVSE console, while the right column identifies signal sources A number of the items differ from those known to be required by FOD personnel, and therefore warrant additional discussion

a t + 10 sec This item refers to the first ten seconds of flight after liftoff This period is critical for aborts, and we feel that a positive indication during, and at the end of, this period is required The signal could be generated at the IMCC by a ten-second timer activated by the liftoff signal The signal would be used to drive a lamp indicator, which would provide a time indication for the LVSE without drawing his attention from other console displays

b "q" Indicator . This is recommended to provide the LVSE with an independent indication of the high dynamic pressure period (It is felt that, although an indication of the critical dynamic stress period will not change his actions in the event of a problem, the indication would help the LVSE to

TABLE 3-1

LVSE - INFORMATION REQUIREMENTS

INFORMATION ITEM	SOURCE
1 Sequence Data	
Lift-Off	Landline lift-off signal
t + 10 *	IMCC generated signal - 10 sec timer started by lift-off signal
t + 40 (shutdown enable)	Shutdown lockout timer's 1 & 2 signals
Max q *	IMCC generated signal - calculated
t + 140 stage enable	Arm stg I shutdown sensor signal (dual signal APS and IPS)
FSECO	Power on TCVPSV (87FS 2) stg I signal
SSI*	91FS1 Engine Start Signal Stg II
APS/IPS staging (separation)	APS staging and IPS staging signals (Requires both signals)
SSECO	Power on TCVPSV (91FS2) stage II signal
Abort Mode Change A*	IMCC derived signal - RTCC actuated when tracking data shows h $\geq$70 K ft
Abort Mode Change B*	IMCC derived signal - RTCC actuated when tracking data shows V$\geq$Vcrit ft/sec
2 Warning Data	
Overrate warning	Overrate signal from GLV rate sensing package
Thrust chamber under pressure SA-1	GLV SA1-MDTCPS A & B signal
t c underpressure SA-2	GLV SA2-MDTCPS A & B signal
t c underpressure SA-3	GLV SA3-MDTCPS A & B signal
APS fail*	IMCC generated signal - limit sense APS analog volts & current signals in tlm (400 cycle ac included)
IPS fail*	IMCC generated - derived from limit sense IPS analog volts & current signals in tlm
Status warning**	IMCC signal - switch actuated whenever malfunction imminent

* recommended items not now contained as such in the list of available parameters

** 3 indicator group to signify either console or systems status

TABLE 3-1 (Concl)

LVSE - INFORMATION REQUIREMENTS

	INFORMATION ITEM	SOURCE
3	Status Data	
	Auto Guidance Switchover	Transfer to redundant control system A & B signals
	Astronaut Guidance Switchover	S/C S/O Command A or B signal
	Stage I Hydraulic Switchover	SA1 & SA2 Hydraulic S/O Command Signal
	Console/Systems go/no go**	Switch actuated to indicate operational status
4	Abort Data	
	RSO Shutdown	Landline - RSO Thrust Termination Signal
	RSO Destruct	Landline - RSO Destruct Initiation Signal
	Astro Shutdown*	Derive from monitoring position of astro shutdown handle
	Left seat ejected	Gemini Spacecraft Telemetry
	Right seat ejected	Gemini Spacecraft Telemetry
	Abort request	IMCC Signal - internal
	Abort command*	IMCC internal derived from abort command transmitted signal
5	Numerical Data	
	Thrust chamber pressure SA-1	GLV telemetry - thrust chamber pressure sensors SA-1
	t c p SA-2	GLV telemetry - thrust chamber pressure sensors SA-2
	t c p SA-3	GLV telemetry - thrust chamber pressure sensors SA-3
	Fuel pressure - stg I A	GLV telemetry - stage I fuel tank pressure sensor A
	Fuel pressure - stg I B	GLV telemetry - stage I fuel tank pressure sensor B
	Fuel pressure - stg II A	GLV telemetry - stage II fuel tank pressure sensor A
	Fuel pressure - stg II B	GLV telemetry - stage II fuel tank pressure sensor B
	Oxidizer pressure stg I A	GLV telemetry - stage I oxidizer tank pressure sensor A
	Oxidizer pressure stg I B	GLV telemetry - stage I oxidizer tank pressure sensor B
	Oxidizer pressure stg II A	GLV telemetry - stage II oxidizer tank pressure sensor A
	Oxidizer pressure stg II B	GLV telemetry - stage II oxidizer tank pressure sensor B
	Hydraulic pressure stg I primary	GLV telemetry - stage I hydraulic pressure sensor, primary
	Hydraulic pressure stg I sec	GLV telemetry - stage I hydraulic pressure sensor, secondary
	Hydraulic pressure stg II	GLV telemetry - stage II hydraulic pressure sensor

* recommended items not now contained as such in the list of available parameters

** 3 indicator group to signify either console or systems status

anticipate the results of any actions taken during this period) The source of such a signal is difficult to identify, but if powered flight is nominal, a pre-calculated time span for the critical period would be reasonably accurate Should the vehicle path not be nominal, a pre-calculated period likely would be inaccurate and virtually useless It seems unlikely that any telemetry measurement of max q will be available, and therefore the IMCC must generate its own indication of the max q period This could be done in one of two ways (1) use pre-calculated max q periods corresponding to probable trajectories, or (2) use a computer-calculated max q period which most closely corresponds to the trajectory of the vehicle The first method has an obvious drawback, an operator must know which max q time to choose if the trajectory is non-nominal He would (if he could make his choice) then manually operate the signal for the MOCR (assuming that controllers other than the LVSE might also use this item) The second method seems more desirable, providing that trajectory information is available to the computer in near real-time and that the computer program can select the period which most closely corresponds to the pre-calculated max q region for that trajectory

c SSI An SSI (Second Stage Ignition) signal is recommended for the LVSE Although second stage ignition failure is perhaps not as critical an abort situation (in terms of crew safety) as other failures at staging, we feel that SSI is desirable information

which should be included as a sequence item To illustrate its use, one might assume two situations (1) the case of a separation failure with second stage ignition, and (2) the case of a separation failure without second stage ignition Case (1) requires a rapid escape, since the flame from stage II would probably burn through the dome of stage I, while case (2) exerts less pressure for crew escape from the vehicle The cases are admittedly hypothetical, but each is possible, therefore, we recommend that each major step of the staging sequence be positively indicated to the LVSE

d APS Fail and IPS Fail These items should be displayed to the LVSE by warning lights in lieu of meter indications of voltage, currents and frequencies We feel that the BTE can and should monitor detailed power system parameters, and that the LVSE requires only an indication that the APS and/or the IPS has failed In this manner the LVSE will notice any rapid failure immediately (a meter has less attention-getting value), and he can be advised of slow degradations by the BTE Further, a slow failure in the APS system will probably be acted upon (if IPS is operative) by the AFDO, and (as will be discussed later) the BTE could also advise this controller

e Astronaut Shutdown and Ejection "Astronaut shutdown", "left seat ejected", and "right seat ejected" should be displayed to the LVSE, primarily so that he can verify astronaut reaction to his

abort command when given. These displays will also indicate abort status if the astronauts initiate a sudden abort for any reason not apparent to the LVSE

f Abort Mode Change We feel that the LVSE should have an indication of each of two abort mode changes, the first to inform him that the ejection mode has ended, and the second to inform him that the retro salvo mode has ended We believe that these signals can be derived and output by the RTCC as discretes to trigger a change of state of an indicator The first of the two abort mode changes can be made at a preset altitude, which can be derived from tracking data The second mode change is made at a preset velocity, and also can be derived from RTCC data

The remainder of the items in Table 3-1 are self-explanatory and require no further discussion

3 2 RECOMMENDED DISPLAYS

Table 3-2 presents displays recommended for the LVSE Column one lists the display item, column two a suggested display device, and column three contains explanatory remarks This table is self-explanatory and warrants no further discussion

TABLE 3-2

LVSE DISPLAY REQUIREMENTS

DISPLAY ITEM	DISPLAY DEVICE	REMARKS
1 Sequence		
Lift off	lamp	Green at lift off
t + 10 } shutdown disable t + 40 }	lamp	Amber at lift off - green at t + 10 - white at t + 40 to signify the critical abort period (amber) and enabling of shutdown capability at t + 40 - stays white after t + 40 to end of phase
Max q	lamp	Ground calculated "time in high dynamic pressure" signifies critical abort period - on amber for period of Max q
t + 140, stage enable	lamp	Green on receipt of "arm stg I shutdown sensor" signal - signifies staging enabled
FSECO	lamp	Green on receipt of "power on TCVPSV (87FS2)" signal - signifies first stage engine cutoff - three level on time, early, late
SSI	lamp	Green on receipt of 91FS1 engine start signal - three level on time, early, or late
APS/IPS staging	lamp	Bilevel lamp green on receipt of both APS staging and IPS staging signals - signifies separation of Stage I from Stage II
SSECO	lamp	Green on receipt of "power on TCVPSV (91FS2) stg II" signal signifies stg II cutoff
Abort Mode Change A/B	lamp	Three level lamp = white from L O to 70K ft, amber from 70K ft to V critical - red after V critical
2 Warning		
Overrate	lamp	Red on receipt of "overrate" signal sensed by GLV rate package
SA-1 thrust chamber pressure	lamp	Red on receipt of SA-1 MDTCPS A & B signal
SA-2 thrust chamber pressure	lamp	Red on receipt of SA-2 MDTCPS A & B signal
SA-3 thrust chamber pressure	lamp	Red on receipt of SA-3 MDTCPS A & B signal - signify underpressures in the respective engines
APS fail	lamp	Amber when telemetry limit sense ckts on APS volts, current or 400 cycle are actuated - signifies failure of Accessory Power System
IPS fail	lamp	Amber when telemetry limit sense ckts on IPS volts or current are actuated - signifies failure of Instrument Power System

TABLE 3-2 (Cont'd)

LVSE DISPLAY REQUIREMENTS

	DISPLAY ITEM	DISPLAY DEVICE	REMARKS
2	Warning (Cont'd)		
	status warning	lamp/ switch	Amber - actuated by LVSE to indicate to FD that a Malfunction is impending
3	Status		
	Auto Guidance S/O	lamp	Amber on receipt of 'transfer to redundant control system A or B - signifies auto transfer from RGS to IGS guidance
	Astro Guidance S/O	lamp	Amber on receipt of "S/C switchover command A or B" - signifies astronauts have initiated a guidance S/O
	Stg I Hydraulic S/O	lamp	Amber on receipt of "SA1 and SA2 hyd S/O commands" - signifies guidance S/O caused by stg I pri - hydraulic failure
	Console System go	lamp/ switch	Green - actuated by LVSE to inform F D that the console and system is operationally ready
4	Abort		
	RSO Shutdown	lamp	Amber - actuated by RSO command to shutdown engines - signifies RSO abort in progress
	RSO Destruct	lamp	Red - actuated by RSO destruct initiate signal - signifies command has been sent for destruction of vehicle
	Astro shutdown	lamp	Amber - actuated when Astro shuts down engines - signifies abort in progress
	Seat ejected right Seat ejected left	lamp	White - split lamp actuated by S/C tlm signals - signifies both Astros have left the S/C
	Abort request	lamp/ switch	Red - actuated by LVSE to inform F D (and others) that he requests abort/or/indicates that another controller has requested abort
	Abort command	lamp/ switch	Red - actuated by LVSE to actuate S/C abort lamps - signifies that the command has been broadcast/or/left IMCC/or/both
5	Numerical		
	SA-1 thrust chamber pressure	digital readouts	0-1KPSIA capability - two readouts four digits each plus identifiers and units for SA-1 and SA-2

TABLE 3-2 (Cont'd)

LVSE DISPLAY REQUIREMENTS

	DISPLAY ITEM	DISPLAY DEVICE	REMARKS
5	Numerical (Cont'd)		
	SA-2 thrust chamber pressure	digital readouts	SA-1 and SA-2 tcp indicated to staging/SA-2 switches to SA-3 at second stage ignition
	Fuel pressure stg I - stg II A sensor	digital readout	0-75 PSIA capability - auto switch to stg II at staging - capability to manually switch to stage II readings at any time during Stage 1 operation
	Fuel pressure stg I/II B sensor	digital readout	
	Oxid press stg I/II, A sensor	digital readout	
	Oxid press stg I/II, B sensor	digital readout	
	Hydraulic pressure stg 1 primary	digital readout	0-4000 PSIA capability - two readouts - four digits plus ident and units stg I primary and secondary to staging - then stg 1 sec switch to stg II press (stg 1 sec should have switch to allow reading stg II pressure at any time before staging)
	Hydraulic pressure stg 1 stg II secondary	digital readout	
6	X - Y Plots		
	Fuel pressure stg I, A or B sensor/stg II A or B sensor	group display scribing projector /or/ plot board	Fuel and oxid pressure plotted on the same surface (dual plot)- plot runs fuel press stg I A and oxid. press stgI A (either or both switchable to sensor B) simultaneously during stg I burn- switches to fuel and oxid pressure stg II A (either or both switchable to B sensor) at staging
	Oxid pressure stg I, A or B sensor/stg II A or B sensor		

TABLE 3-2 (Concl)

LVSE DISPLAY REQUIREMENTS

DISPLAY ITEM	DISPLAY DEVICE	REMARKS
6 X - Y Plots (Cont'd)		
Thrust chamber pressure, SA-1, SA-2 and SA-3	TV display individual monitor	Thrust chamber pressure for SA-1 and SA-2 plotted simultaneously - switch to SA-3 plot at staging
Hydraulic pressure, stg I primary, stg I secondary, stg II	TV display individual monitor	Hydraulic pressure for stg I primary and secondary plotted simultaneously, switches to stg II plot at staging (This plot may be monitored by the BTE)

3 3 INFORMATION REQUIREMENTS AND RECOMMENDED DISPLAYS FOR THE BTE

The information requirements of the BTE (consistent with the philosophy of operation developed in this report) are presented in Table 3-3. All the items on the list are presently included in GLV telemetry or can be derived from telemetry and, as such, are self-explanatory Section 5 presents the reasoning used in assigning these functions to the BTE

Table 3-4 presents the recommended display for the BTE

TABLE 3-3

BTE INFORMATION REQUIREMENTS

	INFORMATION ITEM	SOURCE
1	APS bus voltage	GLV telemetry
2	IPS bus voltage	
3	APS a-c bus voltage	
4	APS a-c frequency	
5	APS current, if used	
6	IPS current, if used	
7	Axial Acceleration, Comp 1	
8	Pitch SMRD BH by pass	
9	Pitch SMRD BL by pass	
10	Roll SMRD BH by pass	
11	Roll SMRD BL by pass	
12	Yaw SMRD BH by pass	
13	Yaw SMRD BL by pass	
14	Overrate	
15	APS volts limit warning	IMCC generated - derived by limit sensing telemetry parameters
16	APS a-c volts warning	
17	APS 400 cycle limit warning	
18	APS current limit warning	
19	IPS volts limit warning	
20	IPS current limit warning	

TABLE 3-4

BTE DISPLAY REQUIREMENTS

DISPLAY ITEM	DEVICE	REMARKS
1 APS bus volts 2 APS bus current 3 APS a-c volts 4 APS a-c frequency 5 IPS bus volts 6 IPS bus current 7 Axial Acceleration	TV display individual monitor	These items shown on a "meter" analog format and are all contained on the same format for simultaneous presentation
8 Pitch SMRD (BH by pass) 9 Pitch SMRD (BL by pass)	lamp	Split indicator - amber each half
10 Yaw SMRD (BH by pass) 11 Yaw SMRD (BL by pass)	lamp	Split indicator - amber each half
12 Roll SMRD (BH by pass) 13 Roll SMRD (BL by pass)	lamp	Split indicator - amber each half
14 Overrate	lamp	red - indicates in parallel
15 APS volts limit warning 16 APS a-c limit warning 17 APS 400 cycle limit warning 18 APS current limit warning 19 IPS volts limit warning 20 IPS current limit warning	lamp	amber lamp series indicating for each that the parameter has exceeded preset limits - (May be augmented with an audible alarm)

SECTION 4

DECISION/ACTION LOGIC

4.1 INTRODUCTION

This section contains detailed decision/action flow diagrams (Figures 4-1 and 4-2) in which LVSE operations are broken down to illustrate decisions and actions that we feel he must make and to illustrate how he would use the recommended displays

4 2 ASSUMPTIONS

A number of assumptions were made so that the decision action processes of the LVSE could be diagrammed These assumptions are listed below with clarifying remarks.

a. Voice override capability. We assume that, by operating a switch on his console, the LVSE can override all A/G communication and can be in direct voice contact with the astronauts

b Abort decision. The LVSE can make an abort decision entirely on his own cognizance (at least during the early portions of the launch) Certain GLV malfunctions will require a rapid reaction from the LVSE, and we assume that in such a case he may act without advising the Flight Director or others

c Abort command The abort command generated by the LVSE console is no more than a signal which activates an abort lamp on the

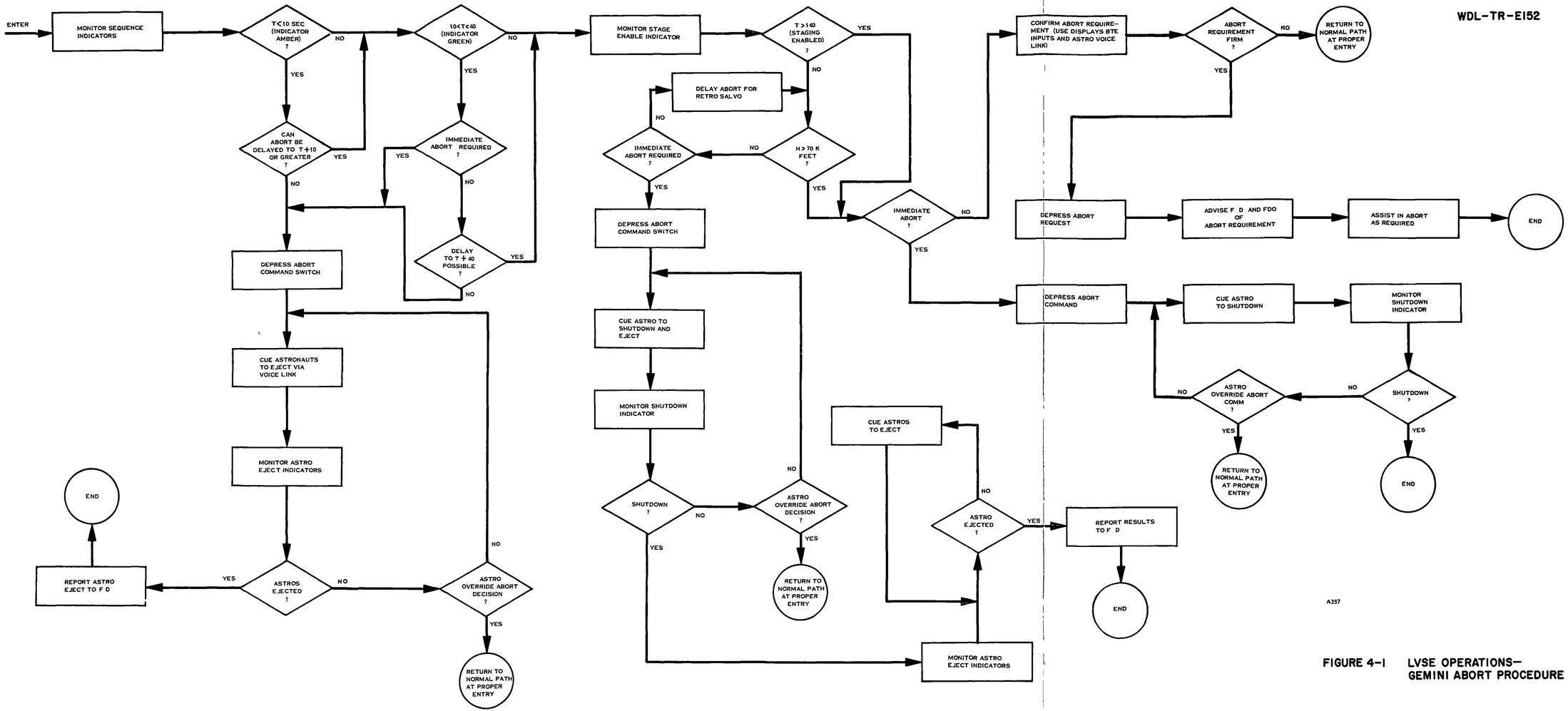

FIGURE 4-1 LVSE OPERATIONS— GEMINI ABORT PROCEDURE

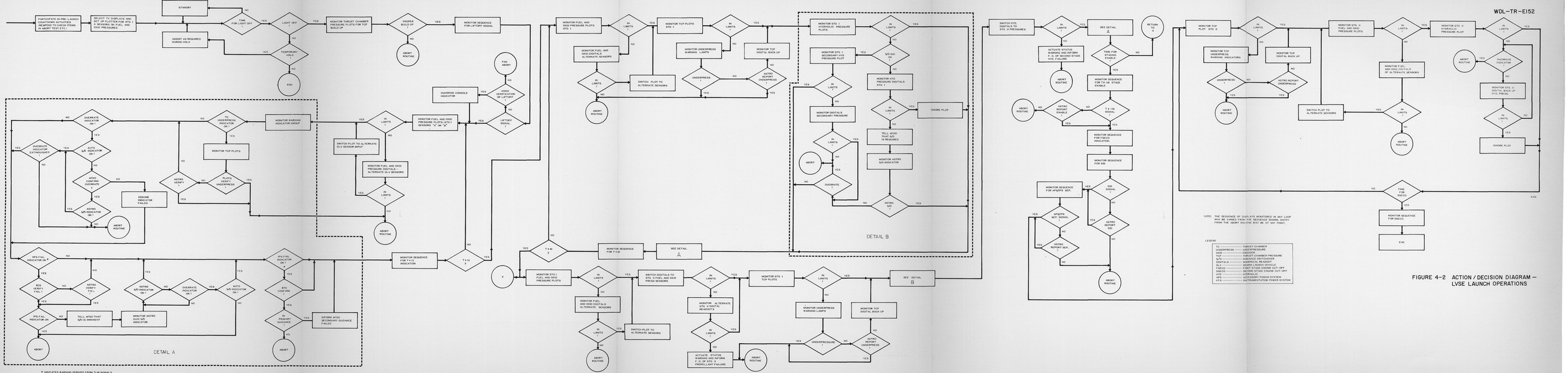
PARTICIPATE IN PRE-LAUNCH COUNTDOWN ACTIVITIES (RESPOND TO CHECK ITEMS AS REQUESTED ETC.)
SELECT TV DISPLAYS AND ALPHA/NUMERIC FOR STG I & II SENSOR FUEL AND OXID PRESSURES
STANDBY
TIME FOR LIGHT OFF ?
LIGHT OFF ?
ASSIST AS REQUIRED DURING HOLD
TEMPORARY HOLD
END
MONITOR THRUST CHAMBER PRESSURE PLOTS FOR TCP BUILD UP
PROPER BUILD UP ?
ABORT ROUTINE
MONITOR SEQUENCE FOR LIFTOFF SIGNAL
PAD ABORT
VOICE VERIFICATION OF LIFTOFF
LIFTOFF SIGNAL ?
OVERRIDE CONSOLE INDICATOR
MONITOR FUEL AND OXID PRESSURE PLOTS-STG I SENSORS "J" OR "K"
MONITOR WARNING INDICATOR GROUP
IN LIMITS ?
SWITCH PLOT TO ALTERNATE GLY SENSOR INPUT
MONITOR FUEL AND OXID ALTERNATE GLY SENSORS
IN LIMITS ?
ABORT ROUTINE
OVERRATE INDICATOR ON ?
AUTO S/O INDICATOR ON ?
AFDO CONFIRM OVERRATE ?
ASTRO S/O INDICATOR ON ?
ABORT ROUTINE
ASSUME INDICATOR FAILED
ASTRO VERIFY ?
PLOTS VERIFY UNDERPRESS ?
MONITOR TCP PLOTS
PU UNDERPRESS INDICATOR ON ?
APS F AIL INDICATOR ON ?
RTC VERIFY F AIL ?
ASTRO VERIFY F AIL ?
APS F AIL INDICATOR ON
TELL AFDO THAT S/O IS IMMINENT
MONITOR ASTRO GUID S/O INDICATOR
ABORT
DETAIL A
ASTRO S/O INDICATOR ON ?
OVERRATE INDICATOR ON ?
AUTO S/O INDICATOR ON ?
IPS F AIL INDICATOR ON ?
RTC CONFIRM ?
IN PRIMARY GUIDANCE ?
INFORM AFDO SECONDARY GUIDANCE FAILED
ABORT
MONITOR SEQUENCE FOR T + 10 INDICATION
T + 10 ?
* INDICATES WARNING DERIVED FROM TLM SIGNALS
MONITOR FUEL AND OXID PRESSURE PLOTS STG I
IN LIMITS ?
MONITOR FUEL AND OXID DIGITALS ALTERNATE SENSORS
SWITCH PLOT TO ALTERNATE SENSORS
MONITOR TCP PLOTS STG I
MONITOR UNDERPRESS WARNING LAMPS
UNDERPRESS ?
ASTRO REPORT UNDERPRESS
MONITOR TCP DIGITAL BACK UP
MONITOR STG I HYDRAULIC PRESSURE PLOTS
MONITOR STG I PU FUEL AND OXID PRESSURE PLOT
S/O IND ON ?
MONITOR HYD PRESSURE DIGITALS STG I
IGNORE PLOT
MONITOR DIGITALS SECONDARY PRESSURE
TELL AFDO THAT S/O IS REQUIRED
MONITOR ASTRO S/O INDICATOR
ABORT
OVERRATE ?
ASTRO S/O ?
DETAIL B
T + 40 ?
MONITOR SEQUENCE FOR T + 40
SEE DETAIL A
X
MONITOR STG I FUEL AND OXID PRESSURE PLOTS
MONITOR FUEL AND OXID DIGITALS ALTERNATE SENSORS
SWITCH DIGITALS TO STG II FUEL AND OXID PRESS SENSORS
SWITCH PLOT TO ALTERNATE SENSORS
MONITOR ALTERNATE STG II DIGITAL READOUT
ACTUATE STATUS WARNING AND INFORM F, S, OF STG II PROPELLANT FAILURE
MONITOR STG II TCP PLOTS
MONITOR UNDERPRESS WARNING LAMPS
MONITOR TCP DIGITAL BACK UP
SEE DETAIL B
SWITCH HYD DIGITALS TO STG II PRESSURES
ACTUATE STATUS WARNING AND INFORM P, S, SECOND STAGE HYD. FAILURE
SEE DETAIL A
TIME FOR SECO ENABLE ?
MONITOR SEQUENCE FOR T + 6 SEC STAGE ENABLE
T + 6 SEC SIGNAL ?
MONITOR SEQUENCE FOR T SECO - 10 SEC INDICATION
MONITOR SEQUENCE FOR 3SE
MONITOR SEQUENCE FOR APS/RPS SEP.
SSE SIGNAL ?
APS/RPS SEP. SIGNAL ?
ASTRO REPORT SEP.
ASTRO REPORT SSE
RETURN TO X
MONITOR TCP PLOT STG II
MONITOR TCP UNDERPRESS WARNING INDICATORS
MONITOR STG II FUEL AND OXID PRESSURE PLOTS
MONITOR FUEL AND OXID DIGITALS OF ALTERNATE SENSORS
MONITOR STG II PRESSURE PLOT
MONITOR STG II OXID BACK UP HYD. PRESS.
IGNORE PLOT
TIME FOR SSECO ?
MONITOR SEQUENCE FOR SSECO
END
NOTE: THE SEQUENCE OF SUBLISTS MONITORED IN ANY LOOP MAY BE VARIED FROM THE SEQUENCE SHOWN. ENTRY FROM THE ABORT ROUTINE MAY BE AT ANY POINT.
LEGEND
TC ——— THRUST CHAMBER
UNDERPRESS ——— UNDERPRESSURE
OXID ——— OXIDIZER
TCP ——— THRUST CHAMBER PRESSURE
S/O ——— GUIDANCE SWITCHOVER
DIGITALS ——— NUMERICAL READOUT
GLY ——— GUIDANCE LAW SAMPLE
FSECO ——— FIRST STAGE ENGINE CUT-OFF
SSECO ——— SECOND STAGE ENGINE CUT-OFF
HYD ——— HYDRAULIC
APS ——— ATTITUDE POWER SYSTEM
IPS ——— INSTRUMENTATION POWER SYSTEM

FIGURE 4-2 ACTION / DECISION DIAGRAM — LVSE LAUNCH OPERATIONS

astronaut's display/control panel Hence, in the true sense, it is a recommendation which the astronauts can accept or not

d Early abort The LVSE may call for an abort in the first ten seconds of flight, if necessary We are aware that certain abort situations (such as the vehicle veering toward the gantry) will be known best by launch site observers, who should originate the abort command for such occurrences Nevertheless, we feel that the LVSE may also detect failures during this period and should be capable of calling for an abort We assume, however, that the LVSE will delay the abort command to beyond ten seconds if the delay is practicable, because we feel that the astronauts will have a slightly improved ejection environment after ten seconds We are aware, too, that such a delay may not always be possible, and have so indicated on the logic diagram in Figure 4-1 Similarly we assume that abort malfunctions occurring in the interval $10 \leq t < 40$ seconds may also be delayed to $t > 40$ seconds to take advantage of engine shutdown capability

e Abort actuation LVSE-actuated aborts are assumed to be initiated by (1) depressing the abort command switch, and (2) by overriding the A/G loop and cueing the abort by voice directly to the astronauts At some currently undefined point in the launch, we assume the Flight Director will change the abort mode, and that, after this change, the LVSE can request an abort only by depressing his abort request switch This procedure seems desirable,

since "high" aborts will require actions and decisions by other flight controllers (such as the Flight Dynamics Officer), and will probably be coordinated by the Flight Director.

SECTION 5

LVSE AND BTE INTERFACES

5.1 GENERAL

This section discusses the interfaces that we believe will be required between the LVSE and BTE and between them and other flight controllers. These interactions will require the use of the intercom system, but should require no special or additional display techniques.

5.2 LVSE/BTE INTERFACE

This interface is the most obvious, because the BTE is an assistant to the LVSE. It appears that the LVSE and the BTE will share a console, thus the intercom system probably will not be used (although its use is not excluded). In our view, the information exchange will be largely one way, that is, from the BTE to the LVSE. During launch, the BTE will furnish information on APS and IPS system performance and spin motor rotation detection status If the BTE has a voice line connected with the launch site crew, he will also be capable of furnishing additional vehicle performance information during both the pre-launch and launch phases

5 3 LVSE/AFDO INTERFACE

The interface between the LVSE and the AFDO (guidance switchover monitor for launch) seems important, because we assume that the AFDO console will not provide information on the GLV systems (such as the hydraulic system). Should a rapid Stage I hydraulic failure occur, switchover of

the guidance from RGS to IGS will be automatic, and no information exchange would be required. It is conceivable, however, that a gradual degradation of Stage I primary hydraulic pressure will be observed by the LVSE, if such a malfunction occurs, we believe that the LVSE will inform the AFDO, estimate the time remaining before an automatic switchover and/or recommend whether or not switchover is necessary before staging. The AFDO will then have a time advantage (albeit slight in some cases) in which to determine best switchover conditions. Other situations (e.g., a failure of the secondary hydraulic system while the primary hydraulic system is operating) lead us to believe that information will be exchanged. Such a situation would exclude any attempt to switchover if the primary system also fails, and the AFDO should be so informed

Information exchanges originated by the AFDO probably will also occur For instance, if the AFDO initiates or plans to initiate a switchover at some point, he should inform the LVSE Also, during guidance switchover caused by an overrate, it appears that the "overrate" warning lamp on the LVSE console may "bounce" on and off once or twice Since the AFDO probably will be better able to judge the effectiveness of the switchover maneuver, he should advise the LVSE whether or not the overrate is corrected

5.4 LVSE/FD INTERFACE

During pre-launch and launch phases, the LVSE will provide status information to the Flight Director at procedurally specified times or whenever requested to do so

Should a malfunction occur which requires an abort, the LVSE will act on his own authority when the situation demands, but will normally warn the Flight Director of the malfunction if time allows Whenever the LVSE acts to abort the mission on his own authority, he will report to the Flight Director that the command has been transmitted and that the astronauts have received it

5.5 BTE/AFDO INTERFACE

This interface is similar to the LVSE/AFDO interface, in that the BTE can furnish "slow" failure information to the AFDO, and can thus provide him with a time advantage. If, indeed, the BTE does monitor APS and IPS power systems performance, he must inform the AFDO of any failure or impending failure that requires a guidance switchover Examples of such failures are as follows

a The drop of APS power to a marginal or out-of-tolerance level

b The failure of the a-c portion of APS such that 400 cycles ac is not available or is out of limits

The guidance equipment will have thresholds of power and frequency both above and below the point at which it will operate properly It, therefore, seems logical to assume that power failures will almost certainly result in overrates or other guidance failures Given this, the AFDO should be informed as soon as a power malfunction is detected to provide as much time advantage as possible to effect a switchover

Similarly, if failures in IPS occur while the APS is still operating, the AFDO should be informed that switchover cannot be accomplished

5.6 BTE/FD INTERFACE

In our estimation, the BTE will furnish status information to the Flight Director when requested. As stated previously, the BTE probably will be a contractor representative. His knowledge of the GLV and his familiarity and close contact with Martin personnel and operations at the launch site will undoubtedly provide the Flight Director with a valuable data source, particularly during pre-launch activities

5 7 LVSE/SPACECRAFT COMMUNICATOR INTERFACE

Instructions for the astronauts or requests for information which do not require the use of the LVSE voice override capability are sent via the Spacecraft Communicator, who coordinates the IMCC voice contacts with the astronauts Hence, an interface between the LVSE and the Spacecraft Communicator is required

SECTION 6

CONSOLE AND DISPLAY/CONTROL CONCEPTS FOR THE LVSE AND BTE CONSOLE

6 1 INTRODUCTION

In this section, a conceptual approach is taken to suggest ways of implementing the GLV monitoring function in the MOCR. No attempt is made to recommend a panel layout because it is felt that recommendations for hardware requirements are beyond the scope of this report Panel layout and the selection of hardware items must be determined and agreed upon by NASA and the implementation contractor

At this time, selection of hardware items is premature because available panel space and the configuration of each standard panel has not been firmly decided Controls and displays are discussed in terms of their correspondence to standard modules under consideration Special controls and displays unique to the GLV monitoring function, which would not ordinarily be included in standard modules, are also indicated The concepts presented below should serve as a guide for the design of the final console configuration

6 2 CONSOLE CONCEPT

At this time, FOD personnel have indicated a requirement for a two-man console in the MOCR for monitoring the GLV Although other operational concepts have previously been presented, we will describe a console from the standpoint of this indicated requirement

This two-man console should be of the same modular type as the other MOCR consoles, and should have either four or five bays Some of the items which determine the number of bays are the inclusion of a pedestal with drawers, which eliminate some knee and leg space, the number of TV monitors required, the amount of panel space required for other display/ control functions, and human engineering considerations such as viewing angles and the distances to controls. If "on-the-job" training is to be used, a minimum of five bays will be needed to allow for seating the trainees

The console should be capable of supporting an additional function after the launch phase. Appropriate logic circuitry must be provided to lock out LVSE and BTE functions at the termination of their duties Some consideration has been given to transforming this console into a command control console after the launch phase No analysis has been performed to determine how much command activity, other than abort requests, will occur during this phase (which would negate this concept), hence, no recommendations are made

A firm requirement exists for a "see-over" console, if our recommendation for placing the fuel-oxidizer plots on one of the large projection screens is adopted

6 3 CONTROL AND DISPLAY CONCEPT

Suggested display devices are indicated in Table 3-2 for the LVSE and in Table 3-4 for the BTE The primary display devices are Y-T

plotters, in which parameters are plotted as a function of time We recommend that the LVSE observe the fuel-oxidizer pressure plots on a large projection screen, and the thrust chamber pressures and hydraulic pressures on TV monitors These plots are sufficiently important to require that they be placed where they will attract the LVSE's attention We recommend placing the plot of fuel pressure and oxidizer pressure on one of the projection screens, because these parameters are of critical importance during the launch phase They will be observed by the Flight Director and the flight dynamics personnel, in addition to the launch vehicle monitoring personnel Plots of hydraulic pressures and thrust chamber pressures will enable the LVSE to anticipate potential catastrophic malfunctions and, in the case of slow-rate system degradations, possibly estimate a time of total system failure The thrust chamber plot will also show how the thrust builds up after first stage and second stage ignition Thrust chamber malfunctions which occur in these periods are very critical

We recommend that digital readouts be used redundantly with the Y-T plots Digital readouts allow a "quick-look" capability not found in other readout devices, including meters In 1949, W F Grether demonstrated that although interpretation times and number of errors were low for both meters and digital readouts, digital readouts were superior for both categories [1] In addition, we prefer to back up analog displays (the Y-T plots) with digital displays, rather than back them up with other analog displays (meters) For those parameters which have constant

1 Stevens, S S , Handbook of Experimental Psychology, John Wiley and Sons, 1951, p 1303

limit values as a function of time, limits would show up as a change in color of the digits

The total number of TV monitors required is three, (See Table 3-2 and Table 3-4) We feel that the remaining displays for both the LVSE and BTE should be placed on digital readouts, message readouts, and discrete status indicators for the reasons which follow The parameters we have chosen for television display (two Y-T plots and one meter format display) will be derived from real-time continuous data This data must be displayed at all times during the launch phase Hence, only one TV format can be shown on each monitor The number of monitors on the console should be restricted to three because of the limited number of input channels available and the demands which other console operators will make on them It therefore follows that other display devices must be used The current console design concept contains provisions for panel modules containing digital readouts, message readouts, and discrete status indicators All of these modules can be programmed in the sense that readouts of different functions and different parameters may be displayed on the same panel module as are phases of the mission change

6 4 MODULE REQUIREMENTS

The modules which are listed below require development of specific modules for specific control and display purposes by the implementation contractor At this time, the modules are still in the design stage and final approval has not been obtained from NASA Description of what these modules should contain for the LVSE and BTE functions are given with the module description

Elapsed Time Module One of these modules is recommended for the console This module contains Ground Elapsed Time (GET) and Greenwich Mean Time (GMT) The digits in the GET portion may be color-coded for T_o + 10 sec and T_o + 40 sec event indications

Event Sequence Module This module should contain the events listed in item 1 of Table 3-1

If this console will be used for other purposes after the launch phase, provisions should be made for including events pertaining to these phases

Lamp Test Module We recommend a lamp test module on the console for checking out all indicators

Digital Display Module A configuration can be made using two digital display modules as a minimum, if each module contains 24 individual read-outs Two identifiers and three-digit accuracy should be adequate for the fuel and oxidizer pressures

Monitor Status Module Under the present concept this module would contain 30 bi-level status indicators, console state of readiness push buttons and a power control push button One of these units would be sufficient for all LVSE and BTE discrete indicators (excluding the event sequence) However, we recommend two units, one for the LVSE and one for the BTE, to allow for sufficient spares and proper human engineering of

the console layout Push button controls should be deleted on the BTE version

Manual Selection Keyboard This keyboard can be used in the Display Request mode to select all of the TV displays needed by the LVSE and the BTE, if it is modified from the present concept by incorporating a push button switch for the third TV monitor This utilization would require that three display system input channels be reserved for the recommended formats during the launch phase

Television Moritor Module As discussed previously, three monitors are recommended

Voice Communications Panel Two communication panels should be provided

Controls Peculiar to LVSE and BTE Functions Provisions must be made, at this console, for an abort command switch, abort test switch, Y-T plotter controls and digital readout controls If this console is to be used for another function, a switch must be provided to lock out the GLV monitoring functions

Note that the above concept does not require a data select keyboard or a standard DCS remote control module at this console unless it would be used for other functions in other mission phases

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